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(54) Abstract Title
Robot cleaning system and a method of connecting a robot cleaner to an external device

(57) A robot cleaner 10 comprises a body 10a, driving means for driving a plurality of wheels 15a-15d located on a body, a camera 14 for capturing external surroundings of the robot cleaner, and a controller 18 for receiving images captured from the camera. Initially, the robot cleaner 10 is connected to a recharging device 30 which charges a battery 19 mounted on the robot cleaner. At this time, the camera 14 captures and stores an image of the external surroundings. Then, the robot cleaner 10 moves away from the recharging device 30 and performs its required cleaning operation. When the robot cleaner 10 needs to return to the recharging device 30, for example, when the cleaning operation has finished or the battery charge level is low, the camera 14 captures an image of the external surroundings at the robot cleaner's current position. The controller 18 compares the received image and compares it with the stored image taken when the robot cleaner was connected with the recharging device 30. By means of this comparison, the controller 18 calculates a return path for returning the robot cleaner 10 to the recharging device 30.

FIG.2

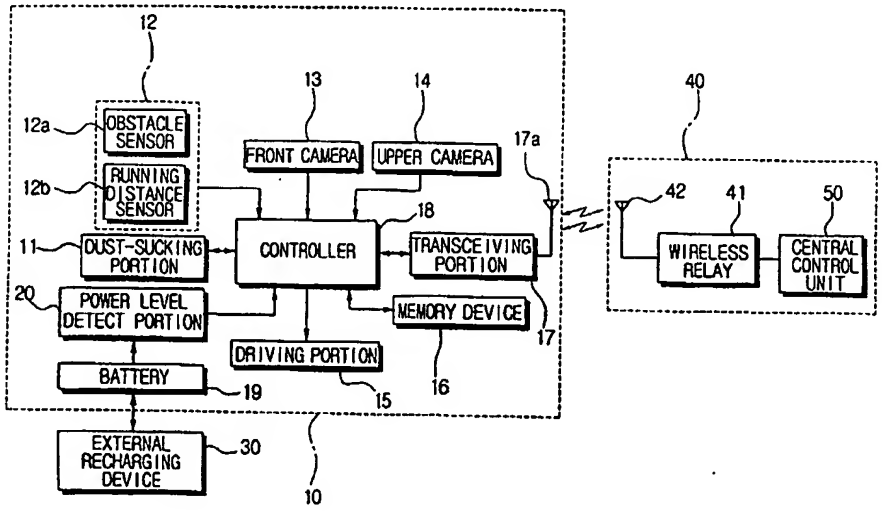

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FIG. 1

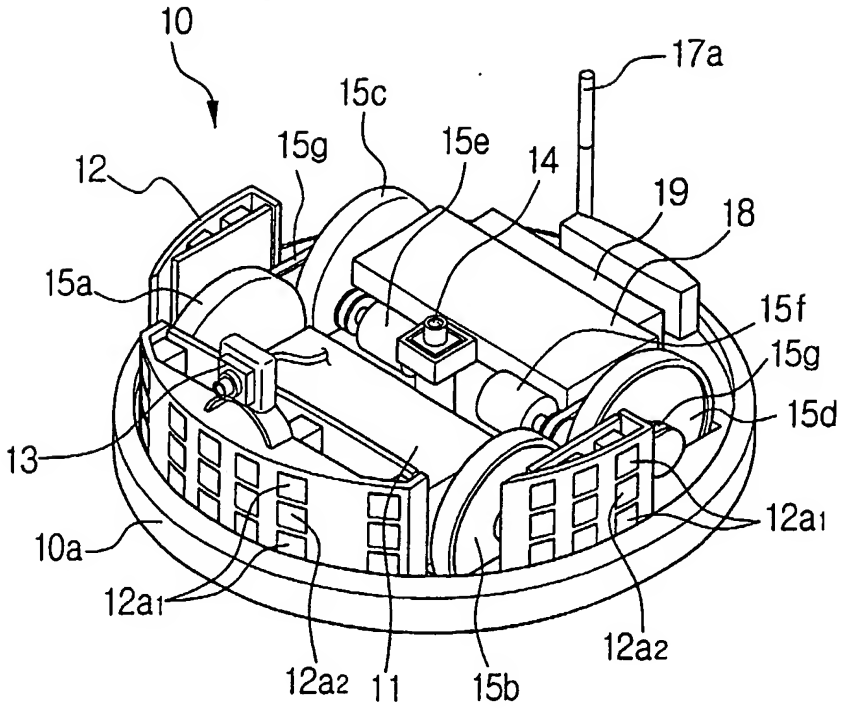

10
17a
15c
15g
15e
14
12
19
18
15a
15f
15g
15d
13
12a1
10a
12a1
12a2
11
15b
12a2

FIG.2

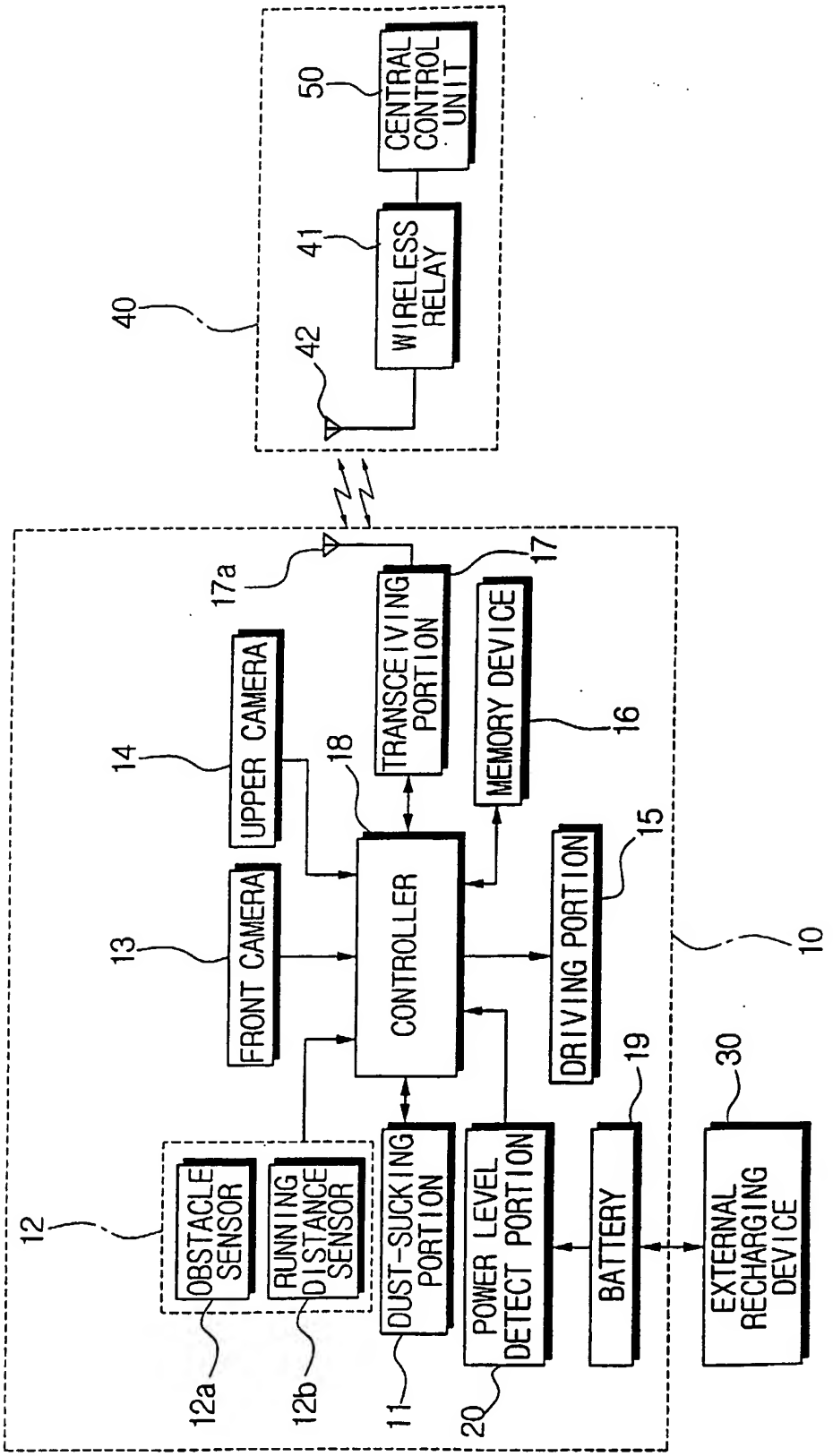

40
50
CENTRAL CONTROL UNIT
41
WIRELESS RELAY
42
17a
17
TRANSCEIVING PORTION
MEMORY DEVICE
16
14
UPPER CAMERA
18
13
FRONT CAMERA
CONTROLLER
15
DRIVING PORTION
10
12
OBSTACLE SENSOR
RUNNING DISTANCE SENSOR
DUST-SUCKING PORTION
POWER LEVEL DETECT PORTION
BATTERY
19
30
EXTERNAL RECHARGING DEVICE
12a
12b
11
20

FIG.3

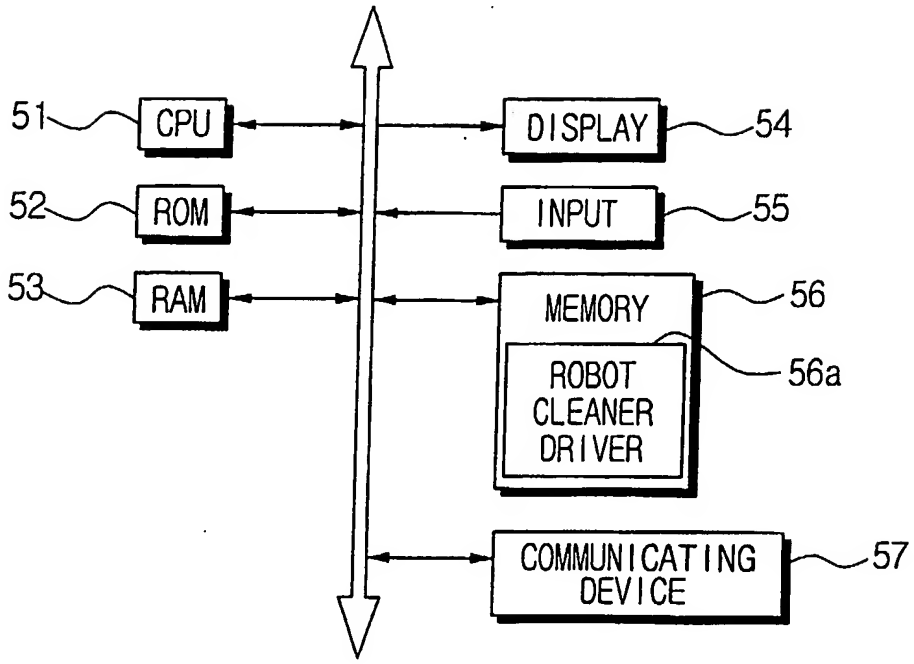

51
CPU
52
ROM
53
RAM
DISPLAY
54
INPUT
55
MEMORY
56
ROBOT CLEANER DRIVER
56a
COMMUNICATING DEVICE
57

FIG.4

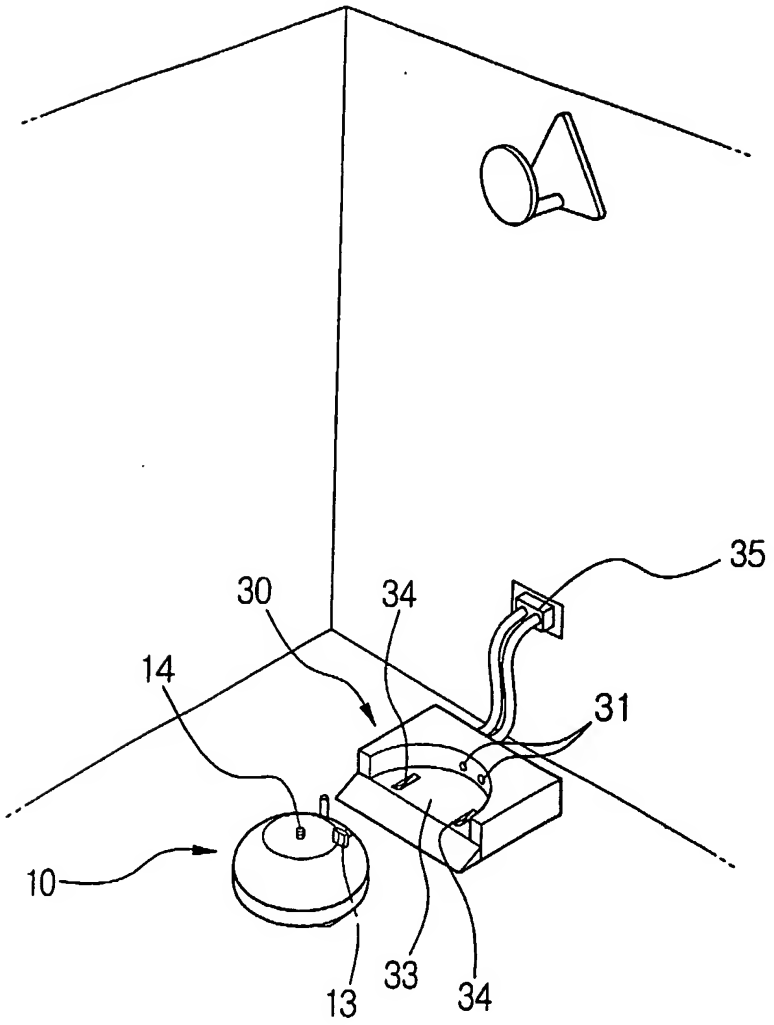


FIG.5

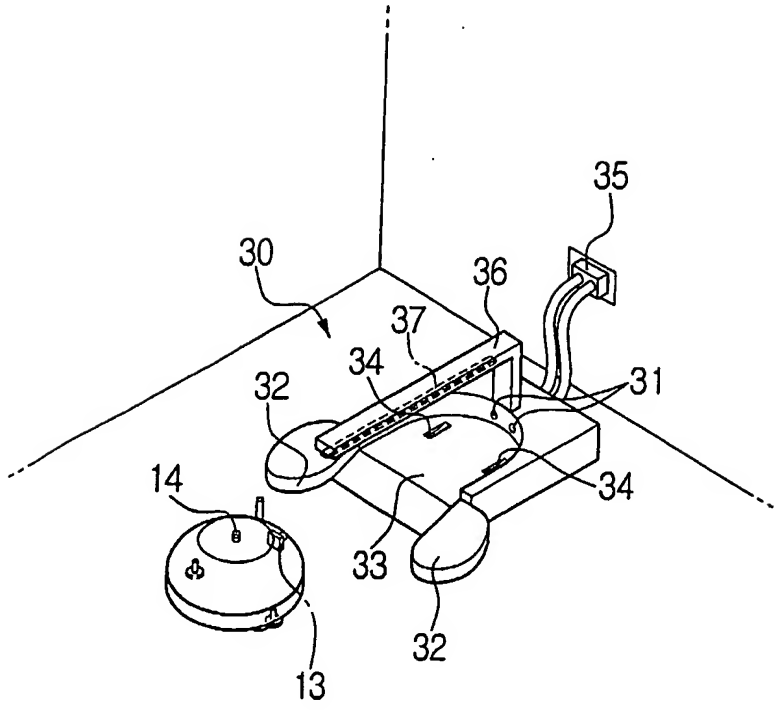

35
30
36
37
34
31
32
34
14
33
32
13

FIG.6

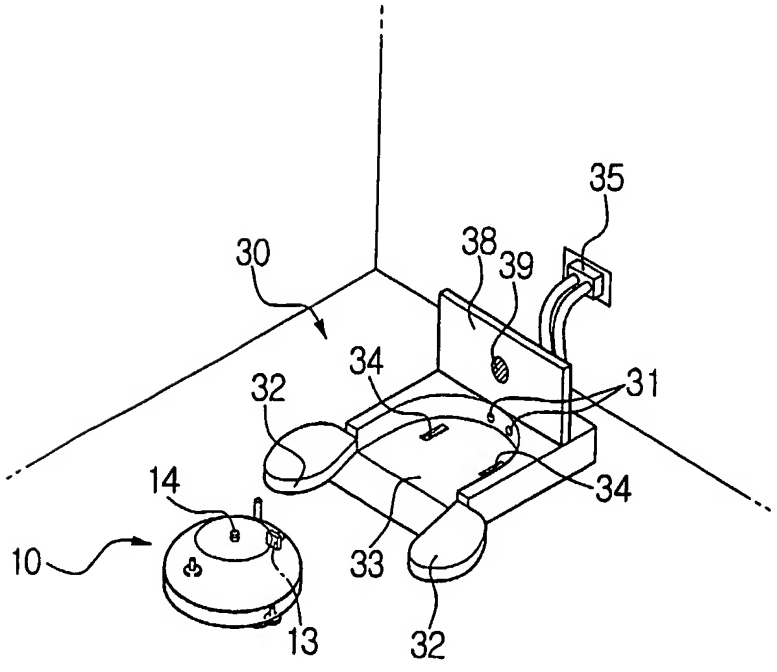
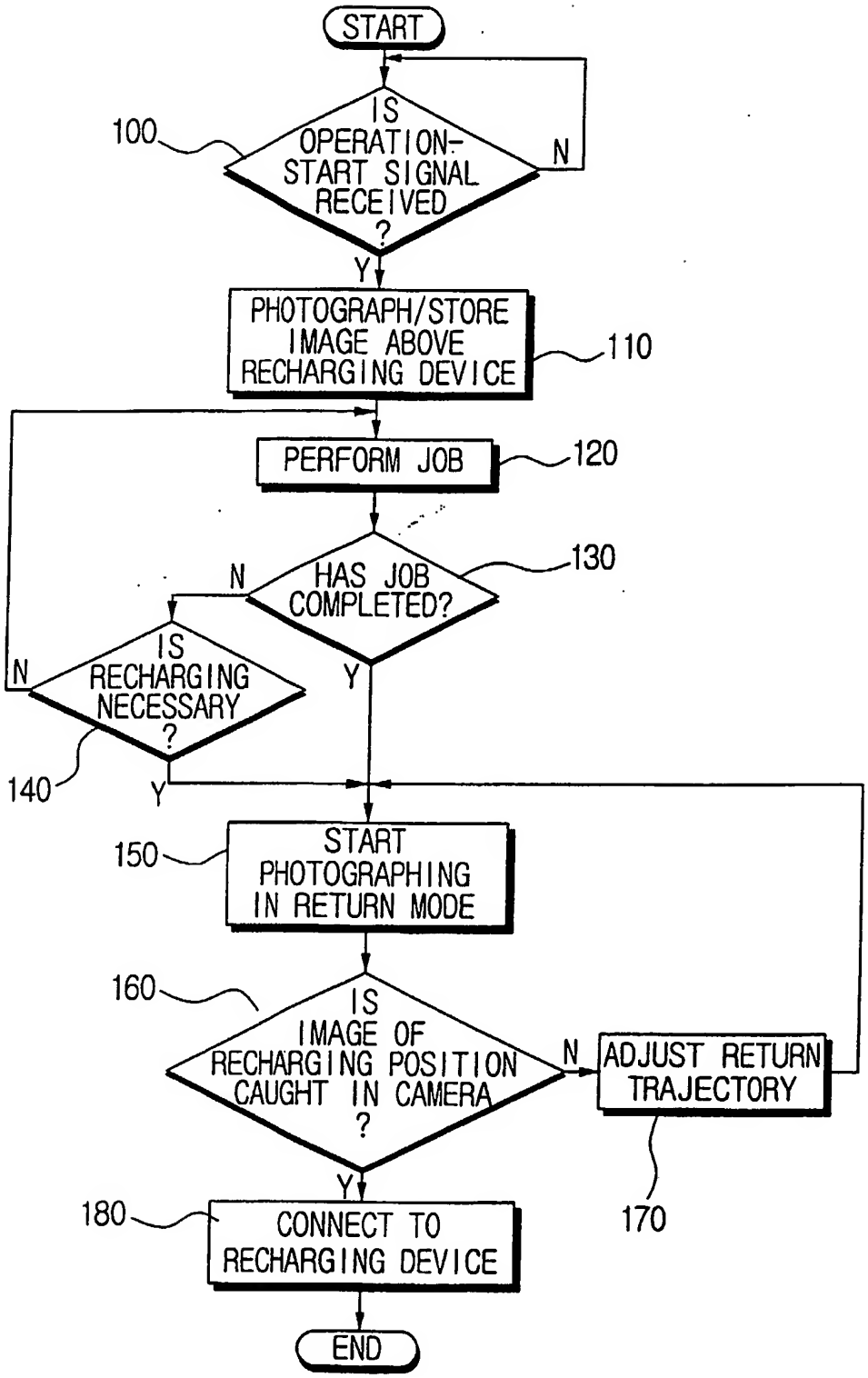

35
38
39
30
34
31
32
34
14
10
33
13
32

FIG.7


START
IS OPERATION-START SIGNAL RECEIVED ?
100
N
Y
PHOTOGRAPH/STORE IMAGE ABOVE RECHARGING DEVICE
110
PERFORM JOB
120
HAS JOB COMPLETED?
130
N
Y
IS RECHARGING NECESSARY ?
N
140
Y
START PHOTOGRAPHING IN RETURN MODE
150
IS IMAGE OF RECHARGING POSITION CAUGHT IN CAMERA ?
160
N
ADJUST RETURN TRAJECTORY
170
Y
CONNECT TO RECHARGING DEVICE
180
END

2376536

ROBOT CLEANER, A SYSTEM USING A ROBOT CLEANER AND A METHOD OF CONNECTING A ROBOT CLEANER TO AN EXTERNAL RECHARGING DEVICE

The present invention relates to a robot cleaner, a system using a robot cleaner, and a method of connecting a robot cleaner to an external recharging device.

Robot vacuum cleaners suck dust and other foreign substances from an underlying surface whilst the cleaner automatically runs over the surface. User effort is therefore reduced. The robot cleaner regularly checks its current position and measures its distance from obstacles such as furniture, office appliances and walls. Accordingly, the robot cleaner is able to clean a particular area whilst being controlled so as not to collide with obstacles located within the area.

Such a robot cleaner is equipped with a battery, which stores the electricity which powers the robot cleaner. The battery is rechargeable, and is periodically recharged by an external charging device. Accordingly, when the battery needs recharging, the robot cleaner has to automatically locate the external recharging device, and then return to it.

To achieve this, the robot cleaner is arranged to receive a high frequency signal which is emitted from the external recharging device. This signal is used by the robot cleaner to detect the location of the external recharging device.

However, this method has disadvantages in that the high frequency signal level is not usually constant, due to effects from reflected waves and from interfering waves. Such a variation in the signal level results in the robot cleaner being unable to find the exact location of the recharging device, and so being unable to dock with the external recharging device.

According to a first aspect of the invention, there is provided a robot cleaner arranged to communicate with an external device over a wireless link, the robot cleaner

comprising: a body; driving means arranged to drive a plurality of wheels located on the body; at least one camera installed on the body, the camera being arranged to photograph external surroundings of the robot cleaner; and a controller arranged to: (a) control the camera, when the robot cleaner is connected to an external recharging device, to capture and store an image relating to a connection position where the external recharging device is located; (b) control the driving means so that, in response to a command signal received from the external device whilst the robot cleaner is connected to the external recharging device, the robot cleaner moves from the connection position of the external recharging device to a further position; and (c) trace a path back to the external recharging device by means of comparing a current image, taken by the camera, with the stored image relating to the connection position.

It is also desirable to provide an external recharging device for enabling easy access and re-connection of the robot cleaner thereto.

The camera can be an upper camera, mounted on the body of the robot cleaner, the upper camera being arranged to photograph objects above the robot cleaner (in relation to its forward running direction). The controller of the robot cleaner may be arranged to receive the image taken above the external recharging device and to store the received image as the image relating to the connection position. The controller generates a path back to the external recharging device by means of comparing an up-to-date image taken by the upper camera, with the stored image relating to the connection position.

Preferably, the robot cleaner also includes a power level sensor for detecting the power level of a battery that is removably mounted on the body. The controller may be arranged to stop a cleaning operation upon receipt of a recharge request signal from the power level sensor, and to control the driving portion so that the robot cleaner returns to the external recharging device.

The robot cleaner can also include a front camera mounted on the body of the robot cleaner, the front camera being arranged to photograph the area in front of the robot cleaner. The controller can be arranged to receive the image taken by the front camera

and to store the image as an image relating to the connection position of the robot cleaner. The controller can then trace a path back to the external recharging device by means of comparing the up-to-date image taken by the front camera, with the stored image relating to the connection position.

According to a second aspect of the present invention, there is provided a robot cleaner system, comprising: a robot cleaner having a body, a driving means for driving a plurality of wheels located on the body, and at least one camera mounted on the body, the or each camera being arranged to photograph external surroundings of the robot cleaner; and a remote controller for wirelessly transmitting control signals to the robot cleaner; the remote controller being arranged to: (a) receive and store an image from the or each camera, the or each image relating to a connection position wherein the robot cleaner is connected to an external recharging device; (b) control the driving means so that the robot cleaner moves away from the external recharging device to a further position when a command signal is received by the robot cleaner; and (c) control the robot cleaner such that the robot cleaner moves back to the external recharging device by comparing a current image taken by the or each camera, with the or each stored image of the connection position at the external recharging device.

Preferably, the remote controller receives an image taken above the external recharging device when the robot cleaner is connected to the external recharging device, and stores the received image as an image relating to the connection position.

It is also preferable that the remote controller stops the robot cleaner upon receipt of a recharging request signal generated by a power level sensor on the robot cleaner. The remote controller may then control the driving portion of the robot cleaner so that the robot cleaner returns to the external recharging device.

According to a third aspect of the present invention, there is provided an external recharging device for a robot cleaner having a camera for photographing external surroundings, the external recharging device comprising: a body on which a power supply terminal is provided, the power supply terminal being arranged to make

connection with a corresponding terminal on the robot cleaner which is connected to a battery of the robot cleaner; a guide member formed on the body and arranged at a position whereby the guide member can be photographed by the camera of the robot cleaner; and a recharging position guiding mark formed on the guide member and arranged at a position such that the guide member can be photographed by the camera of the robot cleaner.

Preferably, the recharging device includes a seat portion in which a groove is formed to receive wheels of the robot cleaner.

The guide member of the recharging device may be formed on the seating portion up to a predetermined height above the seating portion. The recharging position guiding mark may be formed on an underside surface of the guide member.

The external recharging device may include a guide wall extending from the seating portion up to a predetermined height. The guide wall aids advancement or withdrawal of the robot cleaner into/from the seat portion.

The recharging position guiding mark is preferably generally linear.

According to a fourth aspect of the present invention, there is provided a method of operating a robot cleaner having a camera provided thereon, the method comprising the steps of: (a) in response to receiving an operation-start signal when the robot cleaner is connected to an external recharging device, photographing and storing, by means of the camera, an image relating to the recharging position; (b) performing a cleaning operation by means of running the robot cleaner to a position remote from the recharging position; and (c) when the robot cleaner requires recharging, or when the commanded operation has been completed, tracing a path back to the external recharging device by means of comparing a current image, taken by the camera, with the stored image relating to the recharging position, and (d) returning the robot cleaner to the external recharging device.

According to a fifth aspect of the present invention, there is provided a robot cleaner, comprising: a body; driving means arranged to drive a plurality of wheels located on the body; at least one camera installed on the body, the camera being arranged to photograph external surroundings of the robot cleaner; and a controller arranged to: (a) to operate the camera, to capture an image of external surroundings of the recharging terminal when the robot cleaner is connected to the recharging terminal; (b) to operate the camera, to capture an image of the external surroundings of the robot cleaner at its current position when the robot cleaner is detached from the recharging terminal; and (c) to determine a path from the robot cleaner's current position back to the recharging terminal by means of comparing the images captured in steps (a) and (b).

According to a sixth aspect of the present invention, there is provided a robot cleaning system comprising: a robot cleaner having a battery and a camera mounted thereon, the robot cleaner being arranged to move over an area whilst performing a cleaning operation; and a recharging terminal located within the area and being arranged to charge the battery when the robot cleaner is connected to the recharging terminal, wherein the robot cleaner is arranged: (a) to operate the camera, to capture an image of external surroundings of the recharging terminal when the robot cleaner is connected to the recharging terminal; (b) to operate the camera, to capture an image of the external surroundings of the robot cleaner at its current position when the robot cleaner is detached from the recharging terminal; and (c) to determine a path from the robot cleaner's current position back to the recharging terminal by means of comparing the images captured in steps (a) and (b).

According to a seventh aspect of the present invention, there is provided a robot cleaning system comprising: a robot cleaner having a battery and a camera mounted thereon, the robot cleaner being arranged to move over an area whilst performing a cleaning operation; a recharging terminal located within the area and arranged to charge the battery when the robot cleaner is connected to the recharging terminal; and a remote controller for transmitting control signals to the robot cleaner over a wireless link, wherein the robot cleaner is arranged such that, (a) when connected to the recharging device, the robot cleaner transmits an image of the external surroundings of the

recharging device to the remote controller, and (b) when disconnected from the recharging device, the robot cleaner transmits an image of the external surroundings of the robot cleaner at its current position to the remote controller, the remote controller being arranged to compare the images received in (a) and (b) to calculate a path between the robot cleaner, at its current position, and the recharging position, the remote controller thereafter transmitting a control signal, containing the calculated path, to the robot cleaner.

According to an eighth aspect of the present invention, there is provided method of operating a robot cleaner having a camera provided thereon, the method comprising the steps of: (a) in response to receiving a first command signal when the robot cleaner is connected to an external recharging device, photographing and storing, by means of the camera, an image corresponding to the recharging position; (b) performing a cleaning operation by driving the robot cleaner to a position remote from the recharging position; and (c) in response to a second command signal, tracing a path back to the external recharging device by means of comparing a current image, taken by the camera, with the stored image relating to the recharging position, and (d) returning the robot cleaner to the external recharging device.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a robot cleaner, with a cover part removed;

Figure 2 is a block diagram showing the operational elements of a robot cleaner system, the system including the robot cleaner shown in Figure 1;

Figure 3 is a block diagram showing the operational elements of a central control unit of the robot cleaner system shown in Figure 2;

Figure 4 is a perspective view of an external recharging device for recharging the robot cleaner of Figure 1;

Figure 5 is a perspective view of a further external recharging device;

Figure 6 is a perspective view of a yet further external recharging device;

Figure 7 is a flowchart which shows an operating process for causing the robot cleaner to return to one of the external recharging devices shown in Figures 4 to 6.

Referring to Figure 1, a robot cleaner 10 includes a dust-suction portion 11, a sensor portion 12, a front camera 13, an upper camera 14, a driving portion 15, a transceiving portion 17, a control portion 18 and a battery 19.

The dust-suction portion 11 is provided on the body 10a of the cleaner and is arranged to draw in dust from the surface below the dust-suction portion. The dust-suction portion 11 can be constructed in one of a number of known ways. For example, the dust-suction portion 11 may include a suction motor (not shown) and a dust chamber, the dust chamber being arranged to collect dust which is sucked through a suction pipe arranged adjacent the underlying surface.

The sensor portion 12 includes obstacle sensors 12a which are formed on the surface of the body, at predetermined intervals from each other. The obstacle sensors 12a are arranged to emit and receive signals. A distance sensor 12b is also provided, the distance sensor being arranged to measure the running distance of the robot cleaner 10.

Each obstacle sensor 12a includes an infrared light emitting element $12a_1$ that emits infrared light, and a plurality of light receiving elements that receive the reflected rays of the infrared light. The light receiving elements are arranged along an outer circumferential region of the obstacle sensor 12a, in a vertical manner. Alternatively, the obstacle sensor 12a may comprise an ultrasonic sensor that emits ultrasonic waves and receives reflected ultrasonic waves. The obstacle sensor 12a can be used to measure the distance between the sensor and a wall.

The distance sensor 12b can be formed as a rotation sensor that detects the number of revolutions made by wheels 15a to 15d. For example, the rotation sensor can be in the form of an encoder that detects the number of revolutions of motors 15e and 15f, which drive the wheels 15a to 15d.

The front camera 13 is installed on the body 10a and is oriented to photograph objects which are in front of the body, the resulting images being fed as image signals to the control portion 18. A pan and/or tilt camera can be provided to photograph objects which are both in front of and above the robot body 10a.

The driving portion 15 includes a pair of front wheels 15a, 15b at lateral sides of the front portion of the robot body 10a, and a pair of rear wheels 15c, 15d at lateral sides of the rear portion of the robot body. A pair of motors 15e, 15f for rotating the rear wheels 15c, 15d are also provided. A timing belt 15g transmits the driving force generated by the rear wheels 15c, 15d to the front wheels 15a, 15b. In response to control signals from the control portion 18, the driving portion 15 is able to drive the motor 15e in a first direction, and the other motor 15f in the counter direction. Rotation can be achieved by driving the motors 15e and 15f at different rates of revolution.

The driving portion 15 can be constructed without wheels, i.e. by making the driving portion a crawler device.

The transceiving portion 17 is arranged to send data to an antenna 17a, to receive signals from the antenna 17a, and to transfer the received signals to the control portion 18.

The battery 19 is a rechargeable battery and is installed on the body 10a of the robot cleaner 10. Battery recharging terminals (not shown) connected to the battery 19 are provided on the outer surface of the body 10a in such a position that it can be connected to, and separated from an external recharging device (not shown in Figure 1).

A battery charge level detecting portion 20 detects the level of charge in the battery 19, and sends-out a recharge request signal when the charge level detecting portion detects low charge in the battery.

The external recharging device is arranged such that it receives electricity through a power cord connected to a conventional AC power source.

Figure 4 shows a first exemplary external recharging device 30. As Figure 4 shows, the external recharge device 30 has a seat 33 formed in a body thereof. The robot cleaner 10 can be seated in the seat 33. The seat 33 has an open front portion, through which the robot cleaner 10 is received and withdraws. Further, two grooves 34 are formed in the seat 33 and are arranged to receive the wheels 15 of the robot cleaner 10. The grooves 34 are spaced to correspond to the spacing of the wheels 15 on the base of the robot cleaner.

Power supply terminals 31 are formed in a raised rear wall of the seat 33 such that, when the robot cleaner 10 is seated a seated position, the power supply terminals are connected to the recharging terminals of the battery 19. The power supply terminals 31 are connected to the power cord 35 by an internal voltage transformer and power cable. The internal voltage transformer may be omitted.

Figure 5 shows a second exemplary external recharging device 30. This recharging device 30 is arranged to enable easier location of the robot cleaner 10 into the recharging position, and in particular, easier advancing of the external recharging device 30.

Referring to Figure 5, the second external recharging device 30 includes an upper guide member 36, raised above the seating portion 33 by a predetermined distance and disposed thereover. The upper guide member 36 is supported on the rear of the seat 33, and is generally "L" shaped. Guide walls 32 extend forwardly from sidewall portions of the seat portion 33, and are outwardly tapered, gradually increasing the width of the

opening between the guide walls so as to allow easy insertion of the robot cleaner 10 into the seat portion 33. The guide walls 32 effectively form a mouth opening.

In order to allow the upper camera 14 of the robot cleaner 10 to capture an image when it is between the guide walls 32 and located on the seat 33, the horizontal portion of the upper guide member 36 extends from a position above the seating portion 33, to a position generally above the guide walls 32. A positioning mark 37 is formed on the underside of the upper guide member 36, the mark being linear to allow easy recognition of the mark using the upper camera 14. The mark 37 assists in guiding the robot cleaner 10 into the seat 33. The mark 37 is coloured so as to be distinct from the rest of the underside of the guide member 36. This is useful for the following image processing steps. For example, the positioning mark 37 can be coloured black, with the rest of the underside of the upper guide member 36 being coloured white.

Figure 6 is a perspective view of third external recharging device. Here elements referred to previously are referred to by the same reference numerals.

Referring to Figure 6, the third external recharging device 30 includes a vertical guide member 38 extending upwards from the rear of the seat 33 to a predetermined height whereby the vertical guide member 38 is adjacent the front camera 13 of the robot cleaner 10 (when the robot cleaner is seated on the seat 33). The top of the vertical guide member 38 is higher than the height of the front camera 13 when the robot cleaner 10 is seated on the seat 33.

For easy image recognition during operation of the front camera 13, and also for aiding the manoeuvring of the robot cleaner 10 into the recharging position, there is provided a circular guide mark 39 formed near to the centre of the vertical guide member 38.

As before, the guide mark 39 is coloured differently from the rest of the vertical guide member 38.

The control portion 18 processes signals received through the transceiving portion 17, and controls the respective elements (mentioned above) using the received signals. If a key input device (not shown) is provided, e.g. on the body 10a (the key input device having a plurality of keys for setting functions of the respective elements of the robot cleaner 10), the control portion 18 processes signals resulting from data input through the key input device.

When the robot cleaner 10 is turned off, the control portion 18 controls the respective elements such that the robot cleaner 10 is in a standby mode and is, or moves to become connected to (and thus recharged by), the external recharging device 30. By connecting the robot cleaner 10 to the external recharging device 30 when it is in a standby mode (i.e. it is not cleaning), the battery 19 maintains its charge.

When a command signal is received for turning on the robot cleaner 10, the control portion 18 stores, in the memory device 16, images of objects located above the external recharging device 30, the images being photographed by the upper camera 14. Also, images of objects located in front of the external recharging device 30 can be stored, these images being photographed by the front camera 13. When using the external recharging devices of Figure 4 or Figure 5, the control portion 18 stores (in the memory device 16) images of equipment or ornaments located above (which could be images of the position mark 37), which are taken by the upper camera 14.

When using the external recharging device of Figure 6, however, the control portion 18 stores (in the memory device 16) an image of the circular position mark 39 as taken by the front camera 13. An image may be stored of the position mark 39 when the robot cleaner 10 is connected to the external recharging device 30, and/or also when the robot cleaner 10 is removed from the external recharging device 30 and is detached by a predetermined distance.

A 'start operating' signal is used to initiate a cleaning operation, or a monitoring operation, using cameras 12 and 14.

When the robot cleaner 10 returns to the external recharging device 30, the control portion 18 compares currently received images, taken by the upper camera 14, (and/or by the front camera 13), with the stored images of the recharging position. The control portion 18 then performs processing to determine the recharging position, and thereafter controls the driving portion 15 so that the robot cleaner 10 moves towards and connects with, the external recharging device 30.

More specifically, the control portion 18 determines the distance and direction of the robot cleaner 10 from the external recharging device 30 by comparing the stored images (taken above and/or in front of the robot cleaner 10 when connnected to the external recharging device 30) with the images taken at the current time, from above and/or in front of the robot cleaner 10. The control portion 18 controls the driving portion 15 so that the robot cleaner 10 returns from its current position to the destination position, i.e. the position of the external recharging device 30. When driving along the path to the destination portion, the control portion 18 controls the driving portion 15 using information on the current position of the robot cleaner 10 obtained through the measurement of its running distance (measured by the encoder) and by comparing the images above and/or in front of the robot cleaner 10, with the stored images, so that the robot cleaner 10 can trace the required path to the destination position.

In the above-described examples, the control portion 18 directly photographs and stores images from above and/or in front of the robot cleaner 10 when connected to the external recharging device 30, and the robot cleaner 10 returns to the external recharging device 30 using both stored images stored, and images taken at the current time..

In order to reduce the image processing burden on the robot cleaner 10, a robot cleaner system is provided whereby such processing is performed externally. Here, 'processing' means the processing required for returning the robot cleaner 10 to the external recharging device 30.

The robot cleaner 10 is arranged so that the images photographed by the cameras 13 and 14 are transmitted, over a wireless link, for external processing. The robot cleaner 10 is also arranged to operate in accordance with control signals received from an external device, over a wireless link. A remote controller 40 is provided for controlling the robot cleaner 10 over the wireless link, the controller handling processes such as operation control, commands for returning the robot cleaner to the recharging device 30, and the like. The remote controller 40 may include a wireless relay 41 and a central control unit 50.

In the remote controller 40, the wireless relay 41 processes signals received from the robot cleaner 10 and then transmits the processed signals to the central control unit 50 through a connecting wire. The wireless relay 41 transmits the signals received from the central control unit 50 to the robot cleaner 41, through the antenna 42.

A general purpose computer can serve as the central control unit 50, as is indicated in Figure 3. Referring to Figure 3, the central control unit 50 includes a central processing unit (CPU) 51, a read-only memory (ROM) 52, a random access memory (RAM) 53, a display 54, an input device 55, a memory 56 and a communication device 57.

The memory 56 has a robot cleaner driver 56a that controls the robot cleaner 10, and also processes signals transmitted from the robot cleaner 10.

When activated, the robot cleaner driver 56a displays a menu to enable a user to set the manner of control of the robot cleaner. When the user makes a selection from the menu, the robot cleaner driver 56a processes the resulting selection signal so that the robot cleaner 10 performs the selected control operation. Preferably, the menu is divided into several main categories, such as 'cleaning operation' and 'monitoring operation' with each main category being provided with sub-categories which provide a plurality of sub-features supported by the appliance, such as 'target area', 'operating method', or the like.

When an 'operation start' signal is sent to the robot cleaner 10, for example, using the input device 55, the driver 56a receives and stores (in the memory 56) images of the external recharging device 30 using the upper camera 14, and/or images in front of the external recharging device 30 using the front camera 13 when the robot cleaner at a standby mode and connected to the external recharging device 30. Next, the driver 56a controls the robot cleaner 10 to perform the operation 50 as ordered. The control portion 18 of the robot cleaner 10 controls the driving portion 15 and/or the dust-sucking portion 11 in accordance with control information received from the driver 56a through the wireless relay 41, and then transmits the images from above the robot cleaner 10 (taken by the upper camera 14) and/or images from in front of the robot cleaner 10 (taken by the front camera 13) to the central control unit 50 through the wireless relay 41.

When a 'battery recharging' signal is received from the robot cleaner 10, or when a cleaning job is completed, the driver 56a controls the robot cleaner 10 so that the robot cleaner 10 returns to the external recharging device 30. During this control operation, the driver 56a compares the images taken above and/or in front of the robot cleaner 10 when connected to the external recharging device 30 (stored in the memory 56) with the currently received images taken above and/or in front the robot cleaner 10, traces a path to the external recharging device 30, and controls the robot cleaner 10 so that it returns to the exact position of the external recharging device 30.

The process of tracing a path back to the external recharging device 30 will now be described with reference to Figure 7.

In the following description, it is assumed that the initial state of the robot cleaner 10 is a standby mode, with the robot cleaner 10 being connected to the external recharging device 30.

Initially, the system awaits detection of an 'operation start' signal (step S100). When the 'operation start' signal is received, images of the recharging position are taken and

stored for later use (i.e. when the robot cleaner 10 needs to determine its position with respect to the external recharging device 30 (step S110)).

References to the 'images of the recharging position' means images above and/or in front of the robot cleaner 10 when connected to the external recharging device 30, these images being taken when the robot cleaner 10 is connected to the external recharging device 30. When using the external recharging devices described with reference to Figures 5 and 6, the images of the upper position mark 37, or the circular position mark 39, serve as the relevant image of the recharging position.

When the photograph and storage operations are complete, the selected operation is then carried out (step S120). That is, when a cleaning operation is ordered, the robot cleaner 10 is driven so as to become separated from the external recharging device 30 and to run on a predetermined path. Whilst the robot cleaner 10 moves, the dust-sucking portion 11 is operated and sucks in foreign particles from the underlying surface. If a monitoring operation is ordered, the robot cleaner 10 is again driven so as to become separated from the external recharging device 30 to move to a monitoring position. The robot cleaner 10 then photographs targeted objects with the cameras 13 and 14, and transmits and records the photographs taken.

Next, the system determines whether the operation has been completed (step S130). If so, it is then determined whether a recharging operation is required (step S140). If a recharging operation is required, the robot cleaner 10 is controlled to return to the recharging position.

When the cleaner is ordered to the recharging position, return information comprising distance and direction information detailing the distance and direction to the external recharging device 30 is calculated. This calculation is made using trajectory information based on the measured movement of the robot cleaner 10 from the external recharging device 30, and/or from images that are taken by the cameras 13 and 14, and which have been stored once the robot cleaner 10 became separated from the external recharging device 30. Then, using this calculated trajectory information, the driving

portion 15 is controlled to return the robot cleaner 10 to the external recharging device 30.

During the separation and returning movement of the robot cleaner 10 to or from the external recharging device 30, it is preferable that the position is determined using information obtained and recognised by comparing the running distance measured by the encoder, by using the currently received images taken by the cameras 13 and 14, and by using the stored images.

When the robot cleaner 10 is returning to the external recharging device 30, it is determined whether or not stored images of the recharging position have been taken by the cameras 13 and 14 or not (step S160). More specifically, it is determined whether the images taken by the upper camera 14 and/or the front camera 13 include images of the area above the recharging position, or images of the recharging position marks 37 and 39, whether completely or partially.

If the currently received image does not include an image of recharging position, the return trajectory of the robot cleaner 10, i.e. to find the recharging position, is adjusted (step S170). The adjustments made to the returning trajectory include adjustments such as turning or advancing the robot cleaner 10 by a predetermined angle or distance. Steps S150 to S170 are repeated until an image of the recharging position is obtained.

When it is determined that an image of recharging position is included in the current image, the robot cleaner 10 is moved to become connected to the external recharging device 30 (step S180).

In the system shown in Figures 4 and 5, when an image is taken above and /or in front of the robot cleaner when connected to the external recharging device 30, or the upper guiding mark 37 is photographed by the upper camera 14 in step S160, the robot cleaner 10 advances into the seat 33, based on the image information of the images taken above the external recharging device 30, or of the upper guiding mark 37. When the robot cleaner 10 is close to reaching the external recharging device 30 (and so some parts of

the image above the external recharging device 30, or the upper position mark 37 stored in the upper camera 14 are captured), the robot cleaner 10 advances into the seat 33 of the external recharging device 30 while adjusting its trajectory, based on the position information on the guiding mark in an image that is currently received. Accordingly, the upper image or the upper position mark 37 can enable tracing of a predetermined trajectory.

In the system shown in Figure 6, when the recharging position guiding mark 37 is captured by the front camera 13 in S160, the robot cleaner 10 advances to the external recharging device 30 and becomes connected thereto, based on the image information of the guiding mark 37 in S180. That is, the photograph of the circular position mark 39 is compared with the stored image of the position mark 39 in terms of size, degree of distortion, and location within the camera screen. The robot cleaner 10 is then returned to the recharging position along a return trajectory which matches the currently received image of the circular guiding mark 39 with the stored image of the circular guiding mark 39 (step S180).

When the image of the recharging position is caught by the camera 13, based on the position information of the recharging position image currently taken, advancement and positioning of the robot cleaner 10 in the seat 33 is performed with ease, and with less error in the process of docking the robot cleaner 10.

As described above, the robot cleaner 10 is able to return to the external recharging device 30 by using images of the previously stored recharging position and images of the current position of the robot cleaner 10 as taken by the camera. Accordingly, errors in the robot cleaner 10 recognising the position (a problem which often occurs due to external interference signals) are reduced, and errors in the robot cleaner 10 tracing its path to the recharging device can also be reduced.

CLAIMS

1. A robot cleaner arranged to communicate with an external device over a wireless link, the robot cleaner comprising:

a body;

driving means arranged to drive a plurality of wheels located on the body;

at least one camera installed on the body, the camera being arranged to photograph external surroundings of the robot cleaner; and

a controller arranged to:

(a) control the camera, when the robot cleaner is connected to an external recharging device, to capture and store an image relating to a connection position where the external recharging device is located;

(b) control the driving means so that, in response to a command signal received from the external device whilst the robot cleaner is connected to the external recharging device, the robot cleaner moves from the connection position of the external recharging device to a further position; and

(c) trace a path to the external recharging device by comparing a current image, taken by the camera, with the stored image relating to the connection position.

2. A robot cleaner according to claim 1, wherein the camera comprises an upper camera mounted on the body of the robot cleaner, the upper camera being arranged to photograph an area located generally above the robot cleaner, wherein the controller is arranged to capture an image from the upper camera when the robot cleaner is connected to the external recharging device, to store the received image as the image relating to the connection position, and to trace a path back to the external recharging device by comparing the image taken by the upper camera with the stored image relating to the connection position.

3. A robot cleaner according to claim 1 or claim 2, further comprising:

a power level sensor for detecting the power level of a battery mounted on the body, the controller being arranged to cease normal operation upon receiving a

recharging request signal from the power level sensor, and to control the driving means so that the robot cleaner returns to the external recharging device in response to the recharging request signal.

4. A robot cleaner according to any preceding claim, wherein the controller is arranged to control the driving means such that the robot cleaner returns to the external recharging device when the robot cleaner has completed a cleaning operation.

5. A robot cleaner according to any preceding claim, further comprising a front camera mounted on the body of the robot cleaner, the front camera being arranged to photograph an image of the area in front of the robot cleaner, wherein the controller is arranged to receive and store an image of the robot cleaner when it is in the connection position with the external recharging device, and to trace a path back to the external recharging device by means of comparing the image taken by the front camera with the stored image relating to the connection position, when the robot cleaner is commanded to return to the external recharging device.

6. A robot cleaner system, comprising:

a robot cleaner having a body, a driving means for driving a plurality of wheels located on the body, and at least one camera mounted on the body, the or each camera being arranged to photograph external surroundings of the robot cleaner; and

a remote controller for wirelessly transmitting control signals to the robot cleaner;

the remote controller being arranged to:

(a) receive and store an image from the or each camera, the or each image relating to a connection position wherein the robot cleaner is connected to an external recharging device;

(b) control the driving means so that the robot cleaner moves away from the external recharging device to a further position when a command signal is received by the robot cleaner; and

(c) control the robot cleaner such that the robot cleaner moves back to the external recharging device by comparing a current image taken by the or each camera, with the or each stored image of the connection position at the external recharging device.

7. A system according to claim 6, wherein an upper camera is mounted on the body of the robot cleaner and is arranged to photograph an image of the area generally above the robot cleaner, the remote controller being arranged to receive, from the upper camera, an image taken at the time when the robot cleaner is connected to the external recharging device, and to store the received image as an image corresponding to the connection position.

8. A system according to claim 6 or claim 7, further comprising a power level sensor for detecting the power level of a rechargeable battery mounted on the robot cleaner, wherein the remote controller is arranged to cease normal operation of the robot cleaner upon receipt of a recharging request signal generated by the power level sensor, and transmitted from the robot cleaner, and to control the driving means such that the robot cleaner returns to the external recharging device.

9. A system according to any of claims 6 to 8, wherein the remote controller is arranged to control the robot cleaner in such a manner that, when the robot cleaner has completed its cleaning operation, it returns to the external recharging device.

10. An external recharging device for a robot cleaner having a camera for photographing external surroundings, the external recharging device comprising:

a body on which a power supply terminal is provided, the power supply terminal being arranged to make connection with a corresponding terminal on the robot cleaner which is connected to a battery of the robot cleaner;

a guide member formed on the body and arranged at a position whereby the guide member can be photographed by the camera of the robot cleaner; and

a recharging position guiding mark formed on the guide member and arranged at a position such that the guide member can be photographed by the camera of the robot cleaner.

11. A recharging device according to claim 10, wherein the body comprises a seat portion in which a groove is arranged to receive one or more wheels of the robot cleaner, the or each groove being arranged to receive the or each wheel when a recharging terminal of the robot cleaner is connected to the power supply terminal of the recharging device.

12. A recharging device according to claim 10 or claim 11, wherein the guide member is formed above the seat portion at a predetermined height, the guide member being generally parallel to the seating portion, the recharging position guiding mark being formed on an underside surface of the guide member.

13. A recharging device according to claim 12, further comprising a guide wall extending from the seat portion to a predetermined height, and being arranged to guide advancement or withdrawal of the robot cleaner into, or from, the seat portion, wherein the guide member and the recharging position guiding mark extend forwardly by a predetermined length corresponding to the distance from the guide wall to the seat portion.

14. A recharging device according to claim 13, wherein the recharging position guiding mark is generally linear.

15. A recharging device according to claim 10, wherein the guide member is arranged in vertical relation to the body and wherein the recharging position guiding mark is formed on the guide member, the position guiding mark being provided at a position where the guiding mark can be photographed by a front camera of the robot cleaner.

16. A recharging device according to claim 15, wherein the guide member arranged so that it faces a front camera of the robot cleaner when the robot cleaner is seated on the seat portion of the recharging device.

17. A recharging device according to claim 15 or claim 16, wherein the recharging position guiding mark is generally circular in shape.

18. A method of operating a robot cleaner having a camera provided thereon, the method comprising the steps of:

(a) in response to receiving an operation-start signal when the robot cleaner is connected to an external recharging device, photographing and storing, by means of the camera, an image relating to the recharging position;

(b) performing a cleaning operation by running the robot cleaner to a position remote from the recharging position; and

(c) when the robot cleaner requires recharging, or when the commanded operation has been completed, tracing a path back to the external recharging device by comparing a current image, taken by the camera, with the stored image relating to the recharging position, thereby to return the robot cleaner to the external recharging device.

19. A method according to claim 18, wherein, in step (a), the robot cleaner photographs and stores an image of the area generally above the external recharging device.

20. A method according to claim 18, wherein, in step (a), the robot cleaner photographs and stores an image of the area generally in front of the external recharging device.

21. A robot cleaner, comprising:

a body;

driving means arranged to drive a plurality of wheels located on the body;

at least one camera installed on the body, the camera being arranged to photograph external surroundings of the robot cleaner; and

a controller arranged:

(a) to operate the camera, to capture an image of external surroundings of the recharging terminal when the robot cleaner is connected to a recharging terminal;

(b) to operate the camera, to capture an image of the external surroundings of the robot cleaner at its current position when the robot cleaner is detached from the recharging terminal; and

(c) to determine a path from the current position back to the recharging terminal by comparing the images captured in steps (a) and (b).

22. A robot cleaning system comprising:

a robot cleaner having a battery and a camera mounted thereon, the robot cleaner being arranged to move over an area whilst performing a cleaning operation; and

a recharging terminal located within the area and arranged to charge the battery when the robot cleaner is connected to the recharging terminal,

wherein the robot cleaner is arranged:

(a) to operate the camera, to capture an image of external surroundings of the recharging terminal when the robot cleaner is connected to a recharging terminal;

(b) to operate the camera, to capture an image of the external surroundings of the robot cleaner at its current position when the robot cleaner is detached from the recharging terminal; and

(c) to determine a path from the robot cleaner's current position back to the recharging terminal by comparing the images captured in steps (a) and (b).

23. A robot cleaning system comprising:

a robot cleaner having a battery and a camera mounted thereon, the robot cleaner being arranged to move over an area whilst performing a cleaning operation;

a recharging terminal located in the area and arranged to charge the battery when the robot cleaner is connected to the recharging terminal; and

a remote controller for transmitting control signals to the robot cleaner over a wireless link,

wherein the robot cleaner is arranged such that,

(a) when connected to the recharging device, the robot cleaner transmits an image of the external surroundings of the recharging device to the remote controller, and

(b) when disconnected from the recharging device, the robot cleaner transmits an image of the external surroundings of the robot cleaner at its current position to the remote controller,

the remote controller being arranged to compare the images received in (a) and (b) to calculate a path between the robot cleaner, at its current position, and the recharging position, the remote controller thereafter transmitting a control signal, containing the calculated path, to the robot cleaner.

24. A system according to claim 22 or claim 23, wherein the recharging terminal has a target disposed thereon such that the camera of the robot cleaner is directed towards the target when the robot cleaner is connected to the recharging terminal.

25. A system according to any of claims 22 to 24, wherein the camera is arranged to point generally upwards.

26. A system according to any of claims 22 to 24, wherein the camera is arranged to point towards the front of the robot cleaner.

27. A method of operating a robot cleaner having a camera provided thereon, the method comprising the steps of:

(a) in response to receiving a first command signal when the robot cleaner is connected to an external recharging device, photographing and storing, by means of the camera, an image corresponding to the recharging position;

(b) performing a cleaning operation by driving the robot cleaner to a position remote from the recharging position; and

(c) in response to a second command signal, tracing a path back to the external recharging device by comparing a current image, taken by the camera, with the stored image relating to the recharging position, thereby to return the robot cleaner to the external recharging device.

28. A robot cleaner constructed and arranged substantially as herein shown and described with reference to the accompanying drawings.

29. A robot cleaner system, constructed and arranged substantially as herein shown and described with reference to the accompanying drawings.

30. A recharging device constructed and arranged substantially as herein shown and described with reference to the accompanying drawings.

31. A method of operating a robot cleaner, substantially as herein described with reference to the accompanying drawings.

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Application No:	GB 0207634.7	**Examiner:**	Peter Mason
Claims searched:	1-13	**Date of search:**	8 October 2002

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Patents Act 1977
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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): A4F: FSDX
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Int Cl (Ed.7): A47L: 9/00
G05B: 13/02, 15/02

Other: Online: EPODOC, JAPIO, WPI, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2,369,454 A (SAMSUNG KWANGJU ELECTRONICS CO.) See whole document	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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